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Lagoon seepage through soil liners

James P. Murphy

Joseph P. Harner

LAGOON SEEPAGE THROUGH SOIL LINERS

J. P. Murphy [1] and J. P. Harner [1]

Summary

Most compacted soils can be used for lagoon liners to achieve seepage guidelines established by the Kansas Department of Health and Environment.

(Key Words: Lagoon Seepage, Permeability, Soil Lagoon Liner.)

Introduction

This article is a condensed draft of the new Natural Resources Conservation Service's (NRCS) Technical Note 716. Information contained in this draft should not be considered as final NRCS data until the draft is formally approved and distributed.

The protection of surface and groundwater and the utilization or disposal of animal waste are the primary functions of waste storage ponds and treatment lagoons. Seepage from these structures creates risks of pollution of surface water and underground aquifers. The permeability of the soil in the boundaries of a constructed waste treatment lagoon or waste storage pond strongly affects the potential for downward or lateral seepage of the stored wastes.

Research has shown that many natural soils on the boundaries of waste treatment lagoons and waste storage ponds will seal at least partially as a result of physical, chemical, and biological processes. Suspended solids settle out of suspension and physically clog the pores of the soil mass. Anaerobic bacteria produce byproducts that accumulate at the soil-water interface and reinforce the seal. As organic material is metabolized, the soil structure also can be altered. Chemicals in animal waste, such as salts, can disperse soil, which may be beneficial in reducing seepage. Under these conditions, researchers have reported that the permeability of the soil can be decreased several orders of magnitude in a few weeks following contact with an animal waste storage pond or treatment lagoon.

The physical clogging of the soil is considered to be a function of the type of waste, the percent total solids in the waste, and the permeability and the size and geometry of soil pores. Until recently, research has focused on total solids of the waste as the most important factor in the physical sealing process. Research published in the late 1980's convincingly showed that a soil's equivalent pore size computed as a function of particle size distribution and porosity is probably the more important parameter in the physical sealing mechanism. Research has shown that manure sealing will cause a reduction in permeability of 1 to 3 orders of magnitude for all soils. However, for soils with a very high initial permeability, this reduction alone will probably not provide enough protection against excessive seepage and groundwater contamination. Other research has demonstrated that for soils with a clay content exceeding 5 percent for ruminant or 15 percent for monogastric animal manure, a final permeability of 10^{-6} to 10^{-7} cm/sec usually results from manure sealing.

[1]Department of Biological and Agricultural Engineering.

Clay content is defined as the percent by dry weight of a soil that is smaller than 2 microns (0.002 mm).

Site Investigation

A site investigation for a waste storage structure is important to ascertain the potential risk posed by the stored animal waste. Evaluating soils, bedrock, groundwater, climatic conditions, and local water uses provides insight into the potential impact of the site on groundwater resources. Prior to an onsite investigation, you should consult available geology or groundwater maps, published county soil surveys, previous designs in the same physiographic area, and any other information that aids your assessment of the site. Data should include the presence of any water wells or any other water supply sources, depth to the seasonal high water table, general groundwater gradient, general geology of the site, and depth to bedrock, if applicable. Features such as sole source aquifers or important aquifers underlying the proposed site must be noted, because they create a special concern over the impact a site could have.

An onsite investigation always should be conducted at a proposed lagoon or storage pond location. Determining the intensity of any detailed site investigation is the joint responsibility of the designer and the person who has authority to approve the engineering job. The intensity of investigation required depends on the experience in a given area, the types of soils and variability of the soil deposits, the size of the structure, the environmental sensitivity, and an assessment of the associated risks involved. State and local laws should be followed in all cases.

The subsurface investigation can employ auger holes, dozer pits, or backhoe pits. The investigation should extend to at least 2 feet below the planned bottom of the excavation. A site investigation can include field permeability testing or taking samples for laboratory testings, or it can be limited to field classification of the soils. Records from site investigations are important, and the information should be documented and included in the design documentation. When logging soils from auger holes, always consider that the augering can obscure the presence of cleaner sand or gravel lenses by mixing soil layers. Pits and trenches expose more of the foundation, which is helpful in detecting small, but important, lenses of permeable soil. Always use safety rules around trenches.

Soil Properties

The NRCS soil mechanics laboratories have a database of permeability tests performed on over 1,100 compacted soil samples. Experienced NRCS engineers have analyzed these data and correlated permeability rates with soil index properties and degree of compaction of the samples. Based on this analysis, Table 1 has been developed to provide general guidance on the probable permeability characteristics of soils. The grouping of soils is based on the percent fines (percent by dry weight finer than the #200 sieve), Atterberg limits, and degree of compaction of the soils.

Table 2 summarizes a total of 1,161 tests. Where tests are shown at 85 to 90 percent of maximum density, the vast majority of the tests were at 90 percent. Where 95 percent is shown, data includes both 95 and 100 percent degree of compaction tests, with the majority of the tests performed at 95 percent of maximum density. The following general statements then can be made for the four soil groups.

Table 1. Grouping of Foundation Soils According to Their Estimated Permeability

Group	Description
I	Soils that have less than 20% passing a no. 200 sieve and have a plasticity index (PI) less than 5.
II	Soils that have 20 to 100% passing a no. 200 sieve and have a plasticity index (PI) less than or equal to 15. Also included in this group are soils with less than 20% passing the no. 200 sieve with fines having a plasticity index (PI) of 5 or greater.
III	Soils that have 20 to 100% passing a no. 200 sieve and have a plasticity index (PI) of 16 to 30.
IV	Soils that have 20 to 100% passing a No. 200 Sieve and have a Plasticity Index (PI) of more than 30.

Note: Table 1 is revised from the table shown in NRCS Technical Note 716. Additional permeability test data provided the basis for the revised grouping of soils. A plasticity index (PI) of 16 or higher is required for Group III in the new table, compared to a value of 11 in the original table. Soils with PI's from 11 to 16 that were in Group III are now in Group II.

Table 2. Summary of Permeability Test Data from Soil Mechanics Laboratories

Soil Group	Percent of ASTM D698 Dry Density	Number of Observations	Permeability Median K		
			cm/sec	inch/day	inch/year
I	85-90	27	7.2×10^{-4}	24	8760
I	95	16	3.5×10^{-4}	12	4380
II	85-90	376	4.8×10^{-6}	.17	62
II	95	244	1.5×10^{-6}	.048	18
III	85-90	226	8.8×10^{-7}	.030	11
III	95	177	2.1×10^{-7}	.0072	2.6
IV	85-90	41	4.9×10^{-7}	.0168	6.1
IV	95	54	3.5×10^{-8}	.0012	.44

Group I - Generally, these soils have the highest permeability and, in their natural state, could allow excessive seepage losses. Because the soils have a low clay content, the final permeability value will exceed 10^{-6} to 10^{-7} cm/sec.

Group II - These soils generally are less permeable than the Group I soils but lack sufficient clay to be included in Group III.

Group III - These soils generally have a very low permeability, good structural features, and only low to moderate shrink-swell behavior.

Group IV - Normally, these soils have a very low permeability. However, because of their sometimes blocky and fissured structure, they often can experience high seepage losses through cracks that can develop when the material is allowed to dry. They possess good attenuation properties, if the seepage does not move through the cracks.

Regulations of the Kansas Department of Health and Environment (KDHE) require that initial seepage be less than .25 inches per day. The inch/day permeability column in Table 2 shows that most all soils in groups II, III, and IV can be sealed adequately. Remember that the permeability values represented are median values, so some soils in all the groups may have excessive seepage. Testing of existing soils is recommended to assess local conditions. Of the 1,160 soil tests in this table, only the median permeabilities in Group I (43 soil tests) did not meet KDHE regulations. The second column of Table 2 indicates the degree of compaction of the soil (the higher the percent dry density, the greater the compaction of the soil). The four different soil types have been tested at two different compaction rates. The data indicate that additional compaction of the same soil reduces the permeability by a factor of 2 to 13.

Liners are relatively impervious barriers used to reduce seepage losses to an acceptable level. A liner for a waste storage pond can be constructed in several ways. When soil is used as a liner, it often is called a "clay blanket" or "impervious blanket." One method of providing a liner for a waste storage structure is to improve the soils at the excavated grade by discing, watering, and compacting them to a suitable thickness. Soils with suitable properties make excellent materials for liners, but the liners must be designed and installed correctly. Soil has an added benefit in that it provides an attenuation medium for the pollutants.

Those onsite soils in Groups I considered to be unsuitable usually can be treated with bentonite to produce a satisfactory soil liner. Additives such as bentonite or soil dispersants should be added and mixed well into a soil prior to compaction.

Using high quality sodium bentonite with good swell properties is important for this application. The highest quality bentonite is mined in Wyoming and Montana. NRCS soil mechanics laboratories have noted the importance of using the same type and quality of bentonite in the mixtures for lab tests that will be used at the lagoon construction site. Both the quality of the bentonite and how finely ground the product is prior to mixing with the soil affect the final permeability rate of the mixture. You should work closely with bentonite suppliers and your soil testing facility to ensure understanding of these factors.

A soil liner can be constructed by compacting imported clay from a nearby source onto the bottom and sides of the storage pond. This is often the most economical method of constructing a clay liner if suitable soils are available nearby. Liners also can be made from concrete or synthetic materials such as geosynthetic clay and geomembranes. In all cases, liners should provide a reduction in seepage from the storage/treatment pond and diminish the potential for contamination of groundwater.